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Effect of Coating of Dielectric in a 3-Phase GIB with Particle Movement

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ABSTRACT--- The dielectric coating effect on the motion of the Particle inside a Gas Insulated Bus duct (GIB) of three phase using epoxy resin coating of dielectric inside f GIB outer enclosure of inner surface without image charge is presented in this paper. Simulation is performed by considering various parameters like drag, gravitational and the electrostatic forces acting on the particle and a mathematical model was derived. A 2nd order differential equation for the particle motion is solved and restitution coefficient was considered at each impact of particle with the GIB enclosure. At the particle locations, estimation of electric fields instantaneously was made by CSM. The particle motion in the absence of effect of image charge is considered in a 3-phase GIB with dielectric coating. For voltage levels like 220kV, 400kV, 600kV and 800kV class, the movement of radial in nature is found for particles like aluminum and copper inside GIB. Analysis of all the results were done and presented in this paper.

Key Words – GIB, Dielectric coating, Charge Simulation method(CSM), image charge, Breakdown (B.D), partial discharges(PD)

I. INTRODUCTION

There are so many problems associated with AIS (Air Insulated Substation) like dust and salt pollution, meteorological difficulties, considerations of safety, Right of way (ROW), atmospheric pollution etc. Gas Insulated Substations (GIS) offers many advantages. Also, scarcity of land, protection of substation from corrosive environment plays an important role in GIB. With this knowledge, it is essential to shift from the conventional AIS to GIS. Survey studies showed that epoxy coating of certain thickness dielectric material, particularly on the surface inner of enclosure outer of GIB shoots up the B.D voltage. The breakdown strength of compressed SF6 gas will be reduced greatly with the presence of free conducting particles [1]. Reduction in the magnitude of the charge takes place with the coating effect which the particle possesses. One of the advantage of coating is, chances of breakdown of insulation will be reduced greatly in GIB.

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Electric fields local of high intensity in GIB can be decreased with coating of dielectric in GIB inner surface of outer enclosure. Also, resistivity of higher value coating helps in obstructing the expansion, initiation of SF_6 gas pre-discharges. Free metallic particles lift-off field will be increased with the reduction in the charge possessed by the particle [2]. The electric field distribution is non-uniform as the inner surface is not smooth enough in GIB as it leads to reduction the insulation strength. Applying an epoxy coating of suitable thickness of dielectric material on outer enclosure of the inner surface of GIB, the surface of the enclosure will be smooth and even distribution of electric field takes place. As a result, net dielectric strength increases with coating effect .The range of thickness of coating vary from few hundred micrometers to few millimeters [2].

The resting particle on the coated surface gets charged due to different mechanisms such as 1. Conduction using coating 2. Internal discharges (PD) initiation on the surface of the particle.

In this paper, the work is connected with the metallic particle radial movement in 3-ΦGIB with coating on outer enclosure inner surface. For this, CSM technique is used. The parameters in the simulation work are the charge of the particle, the corresponding force and the force of drag which is due to gas viscosity.

II. MATHEMATICAL MODELLING

For the present study, a typical horizontal bus duct having live conductor inner and a coating of epoxy layer on enclosure outer of surface inner of GIB and filled with SF6 gas is taken into account. Let it be assumed that a wire like metallic particle is at rest on the coated enclosure surface, and if the voltage is sufficient enough, it will lift the particle and move in the applied field direction . The particle will lift from its original position when it possesses the required charge, under electric field after the force due to drag and force due to its own weight was overcome. Here various factors like location of particle electric field at the particle location, its weight , gas viscosity, Reynolds's number, drag coefficient and restitution coefficient are taken into account [3]. However, the particle possesses a new charge during its return flight, based on the instantaneous electric field. As per Felici et.al. [4] Work, all the equations are primarily based.Usually, a metallic particle making movement in the presence of field is subjected to various forces like force of Electrostatic (F_e), force of gravity (F_g) and force of drag (F_d).

The particle movement simulation is performed with the equation of motion given below:

$$m\frac{d^2y}{dt^2} = F_e - mg - F_d$$

in which m = particle mass, y = vertical direction displacement, Fe = force due to electrostatic, g = gravitational constant, F_d = Force due to drag.

Finally, the motion of the particle equation can be shown as [3,4]:

$$m\ddot{y}(t) = \left[\frac{\pi \in_0 l^2 E(t_0)}{\ln(\frac{2l}{r}) - l} \times \frac{VSin\omega t}{[r_e - y(t)]\ln(\frac{r_e}{r_i})}\right] - mg$$
$$- \dot{y}(t)\pi r\left(6\mu K_d(\dot{y}) + 2.656\left[\mu\rho_g l\,\dot{y}(t)\right]^{0.5}\right)$$

The equation shown above is a differential equation of non-linear second order and using method of R-K 4th order, the equation can be solved.

III. PARTICLE MOTION SIMULATION

Using CSM, field calculations are performed on the basis of Malik et.al[5] and H.Singer[6] works is compared with analytical method.

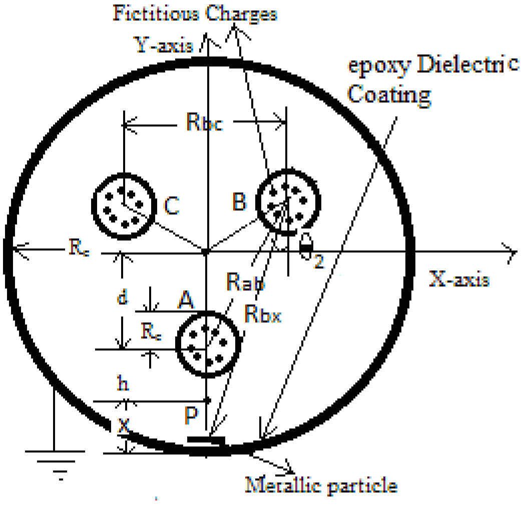

Fig. 1 Electric Field Intensity calculation using CSM. at Point 'P'

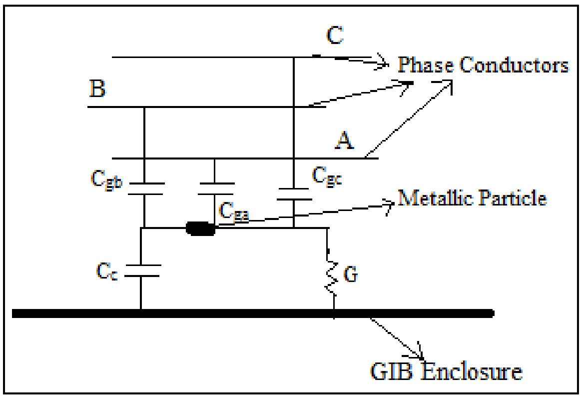

Fig.2 Charging particle mechanism equivalent circuit model coated 3-ϕ GIB

As shown in fig.2, the capacitances are Ca, C_b and C_c between GIB inner conductors & metallic particle By using the equations given below, at point P(x,y)' , the Electrostatic field calculation is performed:

$$E_x = \sum_{i=1}^{3n} \frac{\lambda_i}{2\pi\epsilon}\left[\frac{x - x_i}{\sqrt[3]{(x-x_i)^2 + (y-y_i)^2}}\right]$$

$$E_y = \sum_{i=1}^{3n} \frac{\lambda_i}{2\pi\epsilon}\left[\frac{y - y_i}{\sqrt[3]{(x-x_i)^2 + (y-y_i)^2}}\right]$$

Where components of the field E_x, E_y are along X and Y axes and point 'P' are x, y coordinates in which to be determined is the electric field per phase, λ_i ,the line charge density of i^{th} fictitious charge to be calculated, i^{th} fictitious charge coordinates are x_i, y_i , 'n' fictitious charges total to be found.

IV. RESULTS & DISCUSSIONS

The simulation of movement of particles in radial direction is done for epoxy dielectric coating thickness of 100μm, with t= 1sec, l=12mm, r= 0.01mm, SF_6 gas P= 0.45MPa and 0.9 as Restitution Coefficient for 220kV, 400kV, 600kV and 800kV voltages with calculation of electric fields using CSM and analytical methods and both are compared. The maximum movement patterns in radial direction for particles of Al and Cu for voltage levels mentioned above was simulated for 3-Φ GIB with dielectric coating.

From the obtained simulation results as shown in Table 1, it can be concluded that particles of Al show greater movement in radial direction compared with copper particles which is because the copper particles weight which is higher than silver particles for the same size. With the voltage application increase, also increases the Al and Cu particles movements. From the observations of table 1, It is seen that maximum movement in radial direction is more with analytical field method compared to CSM. The simulation is obtained using advanced C language program.

With the voltage increase, observations show that movement of particles in radial direction is raising with higher voltages and often, it reduces. Also, results show that the particles peak movements in radial direction reduces with thickness of coating of dielectric and is due to the reduction in the charge possessed metallic particles.

Figs 3 to 16 show the movements of particles radially up to the maximum with both the methods of CSM and analytical.

Table 1 Particles Maximum Movement in Radial Direction without image charges

Sl. No.	Voltage (kV)	Name of the Particle	Analytical Field method (mm)	CSM Field method(mm)
1	220	Al	2.3	2.0
		Cu	0.5	0.4
2	400	Al	4.2	3.7
		Cu	1.7	1.2
3	600	Al	8.3	6.6
		Cu	3.1	2.5
4	800	Al	11.8	9.9
		Cu	5.0	3.5

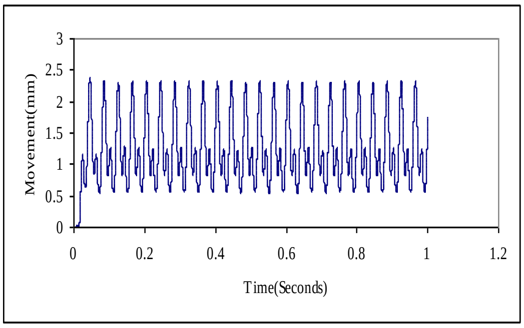

Fig.3 Particle movement of Al with analytical field for 220KV

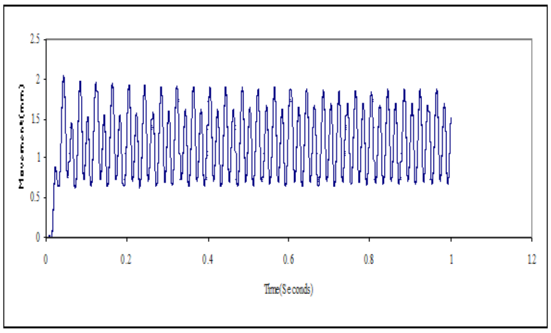

Fig.4 Particle movement of Al for CSM field for220KV

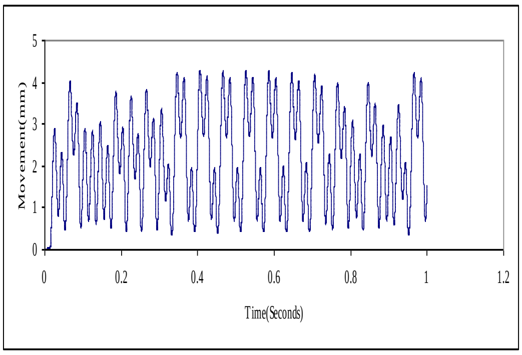

Fig 5 Particle movement of Al with analytical field for 400KV

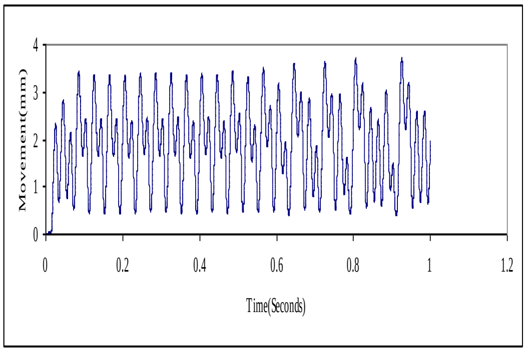

Fig.6. Particle movement of Al with CSM field for 400KV

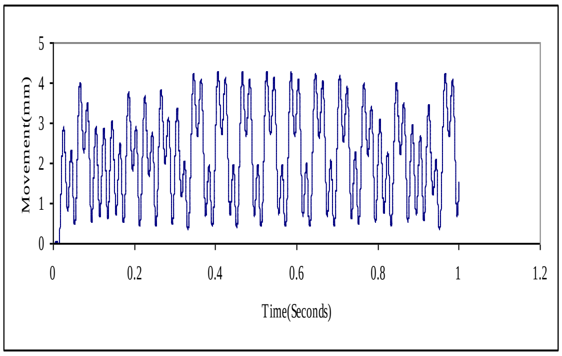

Fig. 7 Movement of Al particle for analytical field for 600KV

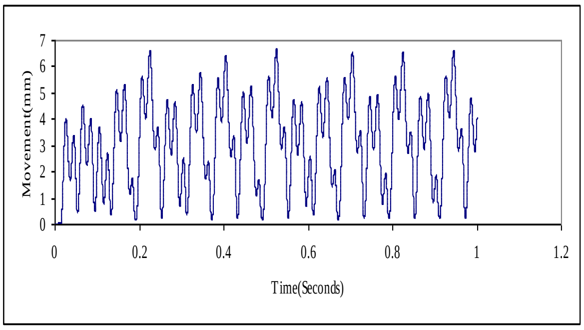

Fig.8 Particle movement of Al for CSM field for 600KV

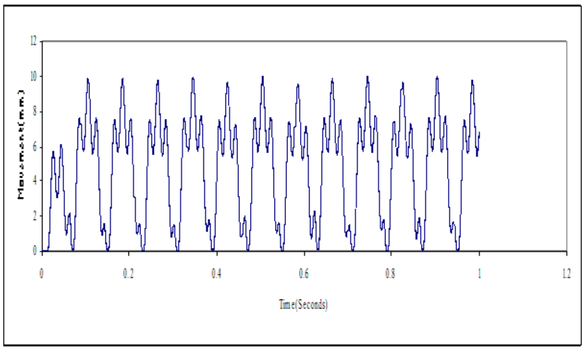

Fig.9. Particle movement of Al for CSM field for 800KV

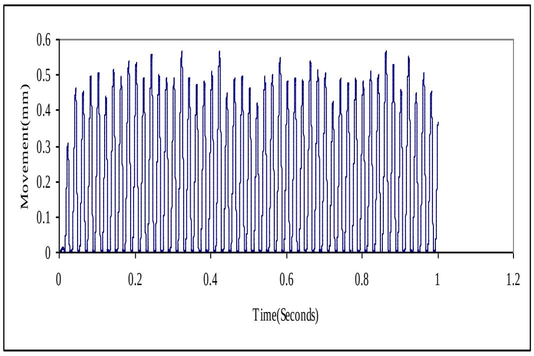

Fig.10 Particle movement of Cu for analytical field for 220KV

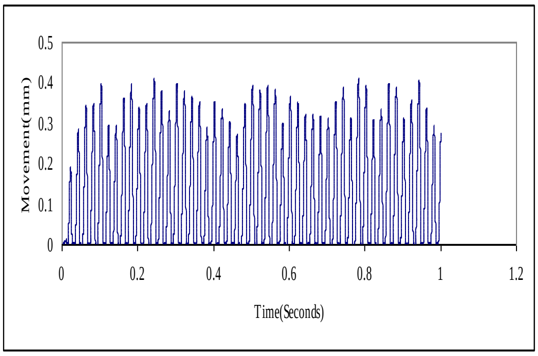

Fig.11. Particle movement of Cu with CSM field for 220KV

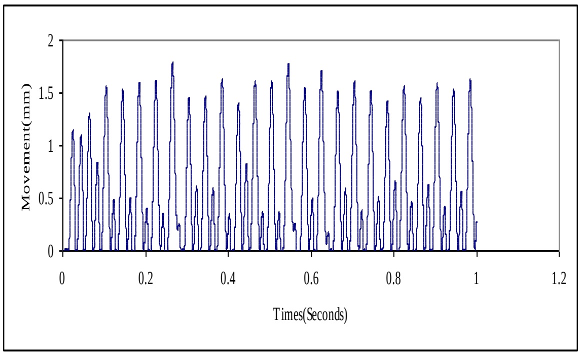

Fig.12 Particle movement of Cu with analytical field for 400KV

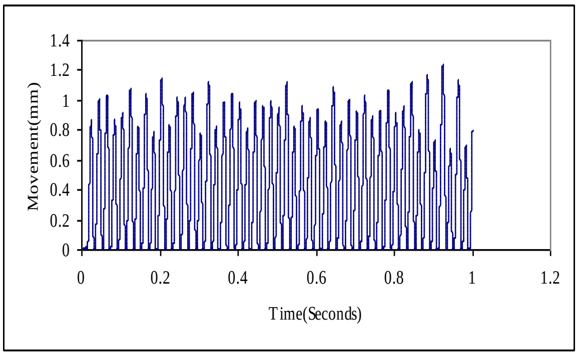

Fig.13. Movement of particle for Cu for CSM field for 400KV

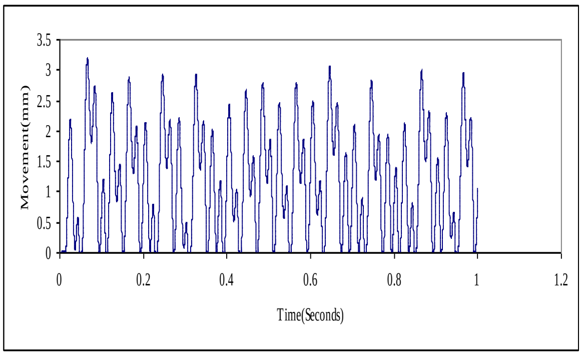

Fig.14. Cu particle movement for analytical field at 600KV

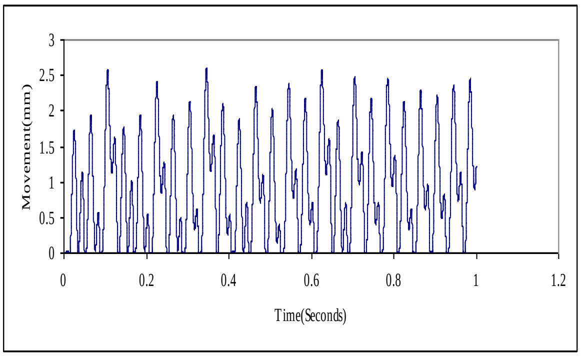

Fig.15 Particle movement of Cu for CSM field for 600KV

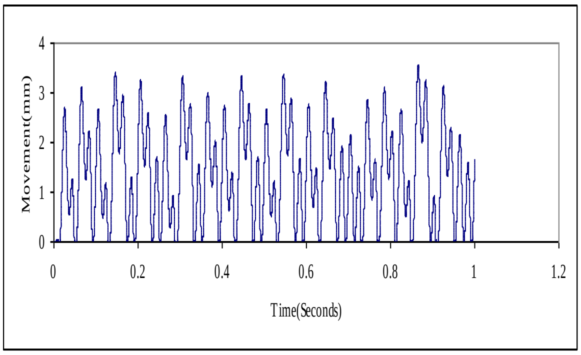

Fig.16. Particle movement of Cu with CSM field for 800KV

V. CONCLUSIONS

By using a suitable dielectric material, the metallic particle charge goes down with coating. In this work, epoxy resin coating of 100 microns thickness is used . The main advantage of dielectric coating is, it obstructs the movement of metallic particles.Using advanced C language program, simulation is performed. For simulating a wire like particle movement, a mathematical model has been developed in a dielectric coated 3-phase GIB. All the results are presented in this work.

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